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ROOTING DEPTH AND DISTRIBUTIONS OF DEEP-ROOTED PLANTS IN THE 200 AREA CONTROL ZONE OF THE HANFORD SITE

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SUMMARY

This study was conducted to document rooting depths and distributions of deep-rooted plants common to the Hanford Site 200-Area plateau. The effort concentrated on excavating plant species suspected of having deep root systems, and species that have been reported in previous studies to contain radionuclides in above ground parts. The information obtained in this study will be useful in modeling radionuclide transport by plants and in designing covers and barriers for decommissioning low-level radioactive waste burial sites.

Fourteen species including 58 individual plants were excavated to measure maximum rooting depth and root density distribution (g dry root/dm^3) through the root zone. Age and canopy volumes of shrubs were also determined. Eight of the 14 species excavated had average rooting depths of 150 cm or more. The two deepest rooted plants were antelope bitterbrush and sagebrush with average depths of 296 and 200 cm, respectively. Gray rabbitbrush had an average rooting depth of 183 cm. Summer annuals, Russian thistle and bursage, had average rooting depths of 172 and 162 cm respectively.

ACKNOWLEDGEMENTS

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INTRODUCTION

The U.S. Department of Energy's Hanford Site is located in south-central Washington State (Figure 1). The 200-Area control zone comprises an area of about 30 square miles and contains a number of radiation zones including covered liquid waste disposal trenches, cribs, and low-level radioactive waste burial grounds (USERDA, 1975). Plants growing on these areas have occasionally been reported to contain levels of radioactive materials above background levels, presumably because their roots penetrated contaminated materials and translocated absorbed radionuclides to the shoots. Most reports of contaminated plants have involved Russian thistle (*Salsola kali*) (Selders 1950, Dabrowski 1973); but radionuclide uptake by shrub species, especially gray rabbitbrush (*Chrysothamnus nauseosus*) has also been involved (Klepper et al. 1978). The research reported in this document was undertaken in order to determine the root system structure and the maximum observed rooting depth of plant species which grow on the 200-Area control zone. Emphasis was placed on species known or suspected to be deep rooted.

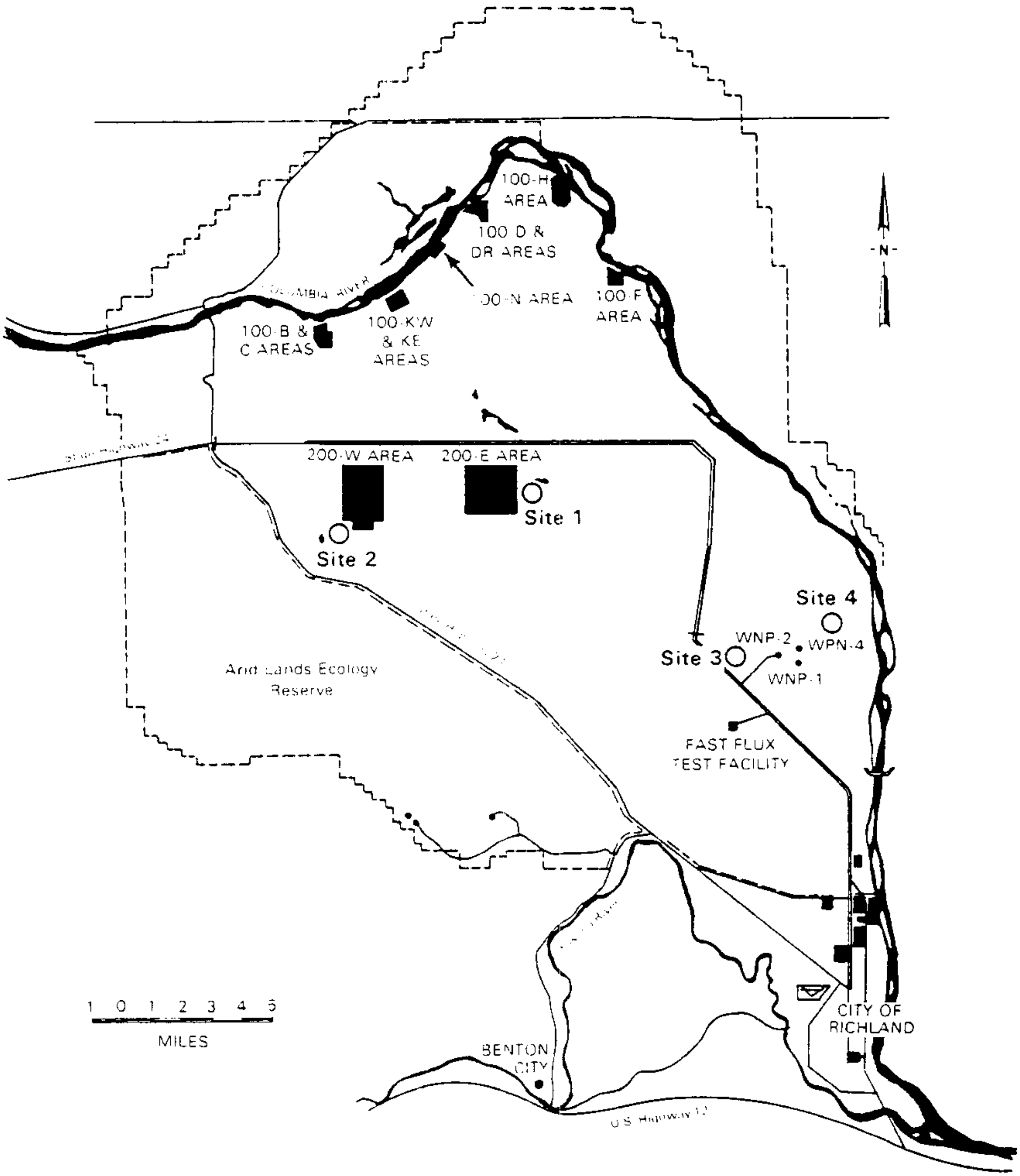

FIGURE 1. Map of the Hanford Site and the locations of the four study sites.

MATERIALS AND METHODS

Excavations of root systems were made either by hand or with a backhoe between May 1975 and April 1976. Canopy volume was calculated from measurements of plant height, width, and length for most of the plants excavated. Age of shrubs was estimated by counting annual rings from a cross section of the plant stem taken near the ground. Depth from the surface to the deepest observed root was determined for 58 individual plants by scraping the face of a trench dug parallel to an isolated specimen. For many plants, samples of soil containing roots were taken so that estimates of rooting density could be made. Samples of 1 dm^3 each were taken in a grid pattern on the trench face beneath the plant (Figure 2). Washed roots from each 1 dm^3 sample were oven dried, weighed, ashed in a muffle furnace, and reweighed. The weight of organic material lost during ashing is reported as a measure of plant root density (g/dm^3).

Soil moisture estimates were obtained by weighing wet and dry soil samples taken at the root excavation sites of sagebrush (*Artemisia tridentata*) and gray rabbitbrush (*Chrysothamnus nauseosus*). Measurements of root depth and shoot height were taken in August 1975 for 22 Russian thistle plants.

Excavations for plant root depth determinations were made at 4 sites: (1) adjacent to the 216-A-24 Crib, (2) adjacent to the 216-S-17 or REDOX Pond Area, (3) about 1.0 km west of the Washington Public Power Supply System (WPPSS) Number Two Plant and (4) approximately 3 km northwest of the WPPSS Number Two Plant (Figure 1). In all, 14 plant species were examined. Emphasis was placed on perennial plants and on summer annuals known to have well-developed root systems. Winter annuals, such as cheatgrass (*Bromus tectorum*), were not sampled.

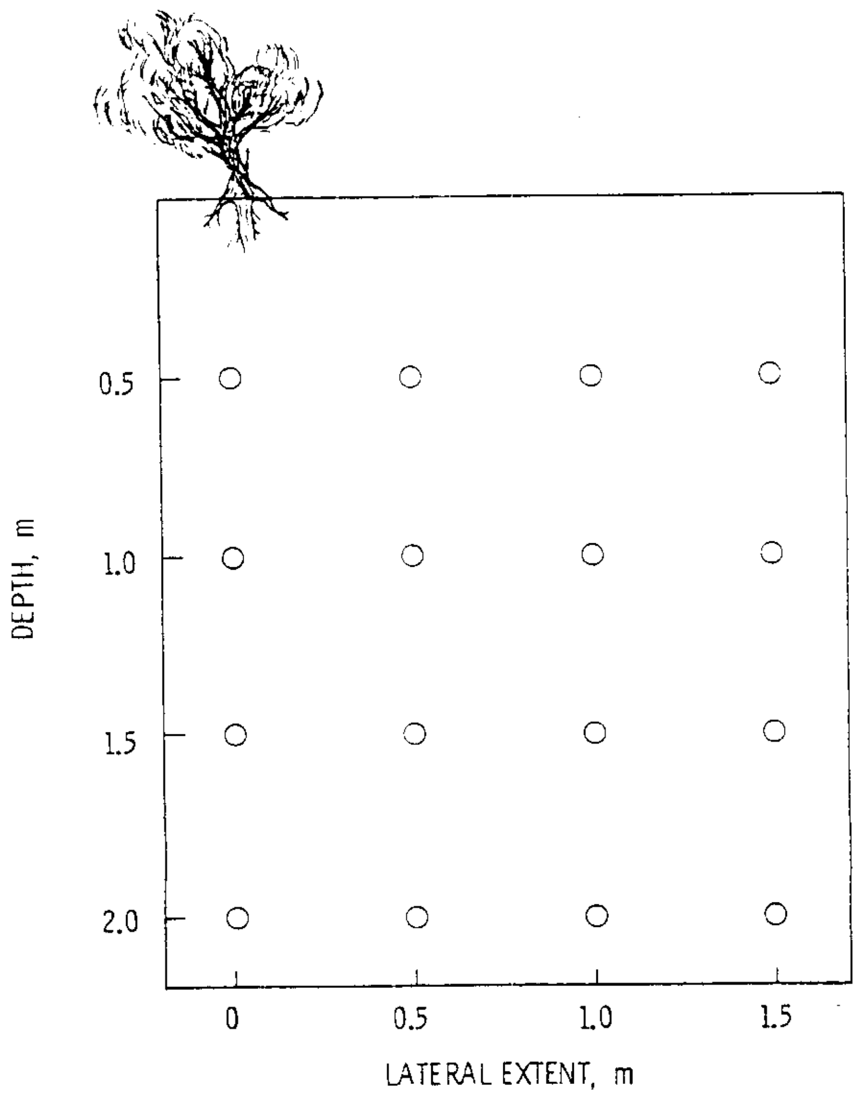

FIGURE 2. Grid pattern used for sampling root density (g dry root/dm^3) at 0.5 m depth increments.

RESULTS AND DISCUSSION

Root systems of the 14 species examined are described in Table 1. All perennial shrubs were tap-rooted except for spiny hopsage (Atriplex spinosa) which, in the one specimen excavated, had a branched root system. The summer annuals, Russian thistle and bursage (Ambrosia acanthicarpa), both showed extensive root system development, but the root system of Russian thistle had the greater density of the two. The two perennial grass species examined were needle-and-thread grass (Stipa comata) and Indian rice grass (Oryzopsis hymenoides). Both species had fibrous roots, but Stipa had mycorrhizal sheaths around most shallow roots and was the deeper-rooted of the two species (Appendix A). Hoary aster (Aster canescens) and prickly lettuce (Lactuca serriola) had shallow tap-roots. Carey's balsamroot (Balsamorhiza careyana) and turpentine cymopterus (Cymopterus terebinthinus) had large storage-type tap-roots. The root system of snowy buckwheat (Eriogonum niveum) consisted of extensive lateral root development but also had a tap-root approximately the same diameter as the laterals.

The average maximum rooting depths of the two deepest rooted species were 296 and 200 cm for antelope bitterbrush (Purshia tridentata) and sagebrush, respectively (Table 2). Eight of the species studied had root systems with average maximum depths of 150 cm or more (Table 2). These eight species include five perennial shrubs, one half-shrub, and two summer annuals. The variability of rooting depth among the individual plants of all species was low, coeficients of variation ranged from .03 - .20 (Table 2). Most shrubs excavated in this study were between 10 and 20 years of age which may explain this low variability. Soil textural properties also were similar among sites. Similar water penetration at each location also would serve to limit plant rooting depth. Plant roots are not capable of penetrating far into air-dry soil (Portas and Taylor 1976), thus rooting depth is limited by the depth of the wetting front. It is also probable that root systems are simply less variable than shoot systems.

TABLE 1. Root system descriptions for the fourteen species studied.

Species	Root System Description
Perennial Shrubs	
Big Sagebrush *Artemisia tridertata*	Tap-root with well-developed laterals in the upper meter.
Gray Rabbitbrush *Chrysothamnus nauseosus*	Strong tap-root with few laterals in upper meter.
Green Rabbitbrush *Chrysothamnus viscidiflorus*	Strong tap-root with few laterals in upper meter.
Antelope Bitterbrush *Purshia tridentata*	Tap-root with a number of small lateral roots in upper meter.
Spiny Hopsage *Atriplex spinosa*	Apparently not tap-rooted; many woody roots in upper meter.
Perennial Grasses	
Needle-and-Thread Grass *Stipa comata*	Fibrous; shallow roots appear to have mycorrhizal sheath.
Indian Rice Grass *Oryzopsis hymenoides*	Fibrous; root system extends about one meter laterally from the center of the plant.
Perennial Herbs and Half-Shrubs	
Hoary Aster *Aster canescens*	Weak tap-root which tapers to single-root size at a depth generally about 10-20 cm. Small laterals.
Turpentine cymopterus *Cymopterus terebinthinus*	Strong storage tap-root which smells of "bitter carrot." Grows more or less vertically.
Carey's Balsamroot *Balsamorhiza careyana*	Strong storage tap-root which does not grow vertically, but tends to be at an angle to vertical.
Snowy Buckwheat *Eriogonum niveum*	Many laterals at about 5-10 cm below the surface; tap-root at 10 cm is no larger than laterals, but does grow vertically.
Summer Annuals	
Russian Thistle *Salsola kali*	Tap-root strong but many laterals present at all depths, especially late in the season.
Bursage *Ambrosia acanthicarpa*	Tap-root, but tapers rapidly. many thread-like laterals.
Prickly Lettuce *Lactuca serriola*	Shallow, weak tap-root; many small laterals, especially in upper few cm.

TABLE 2. Maximum rooting depth of species studied.

Species	Number of Specimens	Sites Sampled	Max Root Depth Mean ± S.E. (cm)	Coeficient of Variation
Big Sagebrush	11	3	200 ± 12	.20
Gray Rabbitbrush	9	2	183 ± 11	.18
Russian Thistle	8	2	172 ± 11	.18
Bursage	5	2	162 ± 8	.11
Antelope Bitterbrush	4	2	296 ± 4	.03
Hoary Aster	4	1	143 ± 4	.06
Needle-and-Thread Grass	4	1	139 ± 8	.12
Indian Rice Grass	3	1	119 ± 4	.06
Turpentine Cymopterus	4	1	145 ± 8	.11
Spiny Hopsage	1	1	195	
Snowy Buckwheat	1	1	150	
Green Rabbitbrush	2	1	153 ± 8	.07
Prickly Lettuce	1	1	85	
Carey's Balsamroot	1	1	140	

Root systems of several plants were sampled to estimate the mean root density for each plant at each 50 cm depth (Figure 2). Sagebrush had a greater root density in the upper meter of the soil profile than did rabbitbrush (Table 3). These data are consistent with the observational information given in Table 1. The soil water profile was presumed to be the same for soils near each species at the beginning of the growing season. Soil samples taken in May 1975, near sagebrush, showed depleted soil water in the upper half-meter of the profile, whereas soil samples taken near rabbitbrush indicated a more even soil water profile throughout (Figure 3). Later in the year (July 25), the soil moisture near sagebrush was depleted in the lower half of the rooting zone while soil moisture near rabbitbrush plants, continued to decrease evenly. Considering the proximity of the soil samples to the respective plants, a pattern of water usage by each plant can be infered.

TABLE 3. Root density, depth to deepest root, canopy volume, and age of shrub for eleven sagebrush and nine rabbitbrush shrubs excavated on the Hanford Site.

Sampling Date	May 1975	May 1975	May 1975	Aug 1975	Oct 1975	Oct 1975	Oct 1975	Oct 1975	Oct 1975	Apr 1976	Apr 1976
Sagebrush											
Age of Shrub (yr)	16	15	--	12	16	16	21	10	--	16	--
Canopy Volume (m^3)	0.88	1.55	6.90	1.04	3.72	8.55	2.12	0.57	0.01	1.48	4.46
Deepest Root (cm)	235	215	172	170	250	245	219	187	114	200	196
Average Root Density at Depth: (g/dm^3)											
50 cm	.020	.053	--	.255	.335	.080	.080	.183	--	--	--
100 cm	.054	.057		.061	.020	.033	.028	.093			
150 cm	.016	.032		.016	.003	.000	.000	.008			
200 cm	.006	.000		.000	.000	.010	.003	--			
250 cm	.000	.000		.000	.000	.000	--	--			
Gray Rabbitbrush											
Age of Shrub (yr)	12	7	9	10	7	6	10	6	6		
Canopy Volume (m^3)	0.87	0.46	0.26	2.93	0.63	0.35	4.90	0.35	0.09		
Deepest Root (cm)	185	250	160	200	210	150	170	147	175		
Average Root Density at Depth: (g/dm^3)											
50 cm	.023	.010	.040	.009	.080	.018	.083	.043	.045		
100 cm	.018	.017	.036	.131	.035	.260	.018	.013	.060		
150 cm	.007	.015	--	.010	.003	.003	.060	--	.028		
200 cm	.000	.006	--	--	.033	.000	.003	--	--		

-- Not Sampled

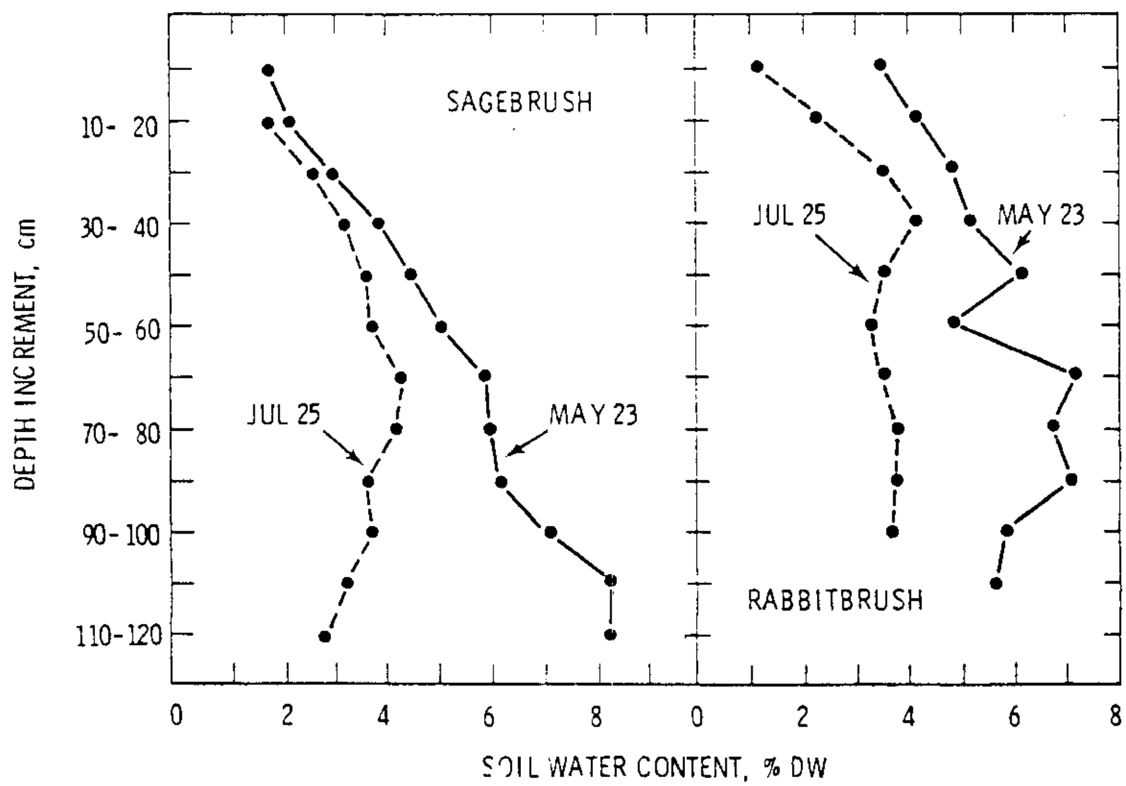

Figure 3. Soil-water profile near sagebrush and rabbitbrush. Data represent averages of two or more samples except for July rabbitbrush.

Root systems of Russian thistle plants had greater root density than did bursage (Table 4) and both species had greater densities later in the year when they matured. Larger plants generally had greater root densities. Average root densities of Russian thistle plants were similar to those of sagebrush plants and bursage roots were similar to rabbitbrush (Table 5).

TABLE 4. Root density, depth to deepest root, canopy volume, and shoot dry weight for eight Russian thistle plants and five bursage plants excavated on the Hanford Site.

Sampling Date	Aug 1975	Aug 1975	Aug 1975	Aug 1975	Aug 1975	Oct 1975	Oct 1975	Oct 1975
Russian Thistle								
Shoot Dry Weight (g)	720	15	253	14.5	344	--	--	--
Canopy Volume (m^3)	0.78	0.09	0.64	0.09	0.88	3.89	0.39	1.77
Deepest Root (cm)	190	118	150	145	183	209	205	172
Average Root Density at Depth: (g/dm^3)								
50 cm	.023	.009	.003	.149	.271	.733	.033	.138
100 cm	.038	.010	.027	.069	.118	.120	.013	.023
150 cm	.002	.000	.007	.005	.075	.003	.003	.003
200 cm	.000	.000	.000	.000	.007	.000	--	--
Bursage								
Shoot Dry Weight (g)	42	30	51			--	--	
Canopy Volume (m^3)	0.19	0.18	0.25			0.36	0.23	
Deepest Root (cm)	165	180	165			133	167	
Average Root Density at Depth: (g/dm^3)								
50 cm	.032	.029	.008			.033	.063	
100 cm	.013	.006	.027			.020	.023	
150 cm	.008	--	--			.003	.017	
200 cm	--	--	--			--	--	

-- Not sampled.

TABLE 5. Mean ($\bar{x}$ ± S.E.) root density (g of oven dry root/dm^3) at 50 cm increments for sagebrush, gray rabbitbrush, Russian thistle, and bursage.

Depth	Sagebrush	Rabbitbrush	Russian Thistle	Bursage
50	.144 ± .044	.039 ± .009	.170 ± .060	.033 ± .015
100	.049 ± .019	.065 ± .027	.052 ± .018	.018 ± .008
150	.011 ± .004	.014 ± .006	.012 ± .004	.009 ± .005
200	.003 ± .001	.005 ± .004	.001	--
250	.000	--	--	--

-- Not Sampled

On 11 August 1975, 22 Russian thistle plants were excavated and measurements taken of root depth and shoot height. Roots for these young plants were roughly 4 times as long as the shoots were tall (Figure 4). However, this relationship appears to change as the plants approach maturity. Mature plants excavated in October had roots that were approximately twice as deep as the shoots were tall.

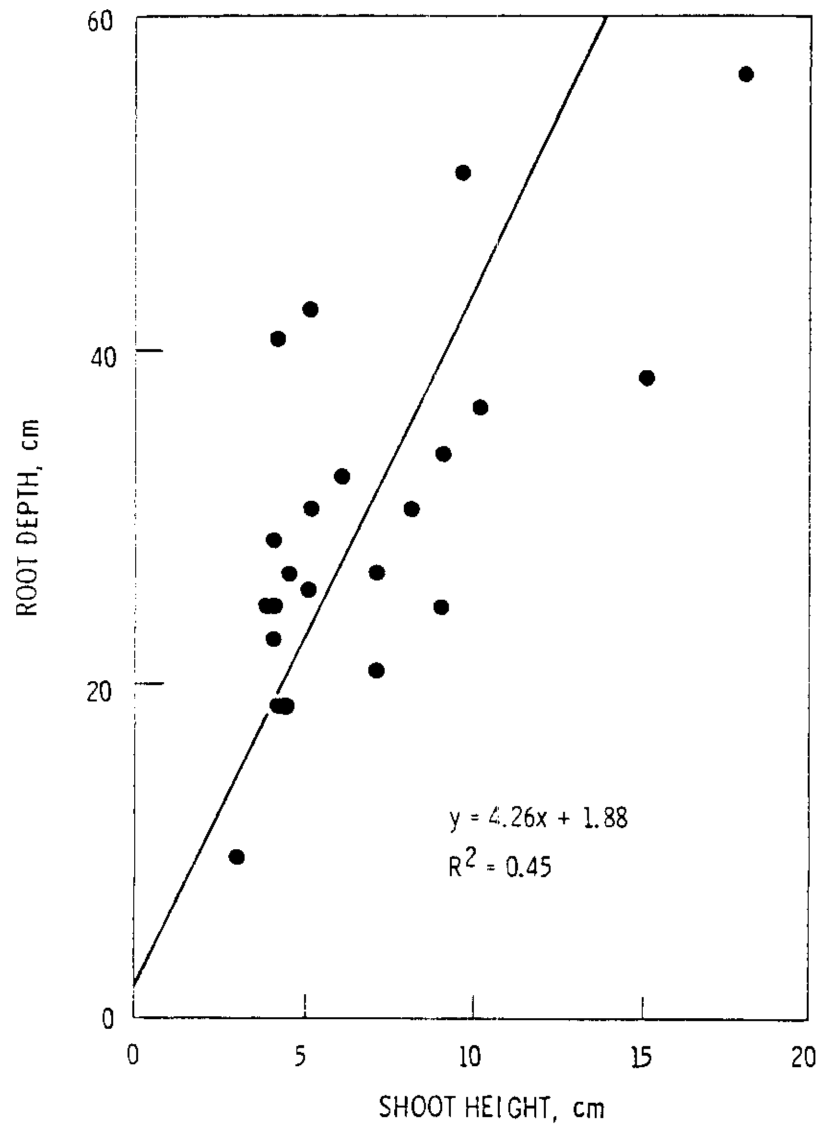

FIGURE 4. Root depth and shoot height for young tumbleweed plants sampled in August.

CONCLUSIONS

Eight out of fourteen species examined in this study had root systems which extended below 150 cm (about 5 feet) in depth. The deepest was antelope bitterbrush, which penetrated to 300 cm (about 10 feet). Second deepest was big sagebrush, which penetrated to 200 cm. These two shrubs are the climax species on the Hanford Site (Daubenmire 1970) and will continue to be important components of this vegetation unless a climatic change occurs. Gray rabbitbrush is also an important species in this vegetation type. The average rooting depth for the nine plants sampled in this study was 183 cm. This species is quick to invade disturbed land and will also persist in this area (Daubenmire 1970). These deep-rooted shrubs occur in many undisturbed areas on the Hanford Site and could be expected to become the predominant shrub on disturbed locations of the 200-Area plateau. Spiny hopsage also appears to be a deep-rooted shrub. The one specimen excavated in this study had a rooting depth of 195 cm. Though deep-rooted, this species occurs in silty alkaline soils and seldom on the sandy well drained soils of the 200 Area plateau.

The annual forbs, Russian thistle and bursage are common to all sandy areas of the Hanford Site and are quick to invade disturbed sites (Cline et al. 1975). The average rooting depths for these two species were 172 and 162 cm, respectively. These annual species can produce in one growing season a root system of similar depth and distribution to that of the shrubs which take several years to develop. Thus, these early invading annual species have a greater potential for transporting buried radioactive materials to the surface than do the shrubs in the short term. However, once established, shrub species have the potential for translocating buried wastes from their deep roots throughout the growing season.

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APPENDIX A

OTHER PLANTS EXCAVATED DURING THIS STUDY

Appendix A.

Depth to deepest root (cm), age (yr), canopy volume (m^3), and mean root density (g/dm^3) for other plants on the Hanford Site.

	Plant Number			
Purshia tridentata	#1	#2	#3	#4
Age	27	25	--	--
Canopy Volume	2.68	2.99	4.16	3.76
Deepest Root	300	283	300	300
Chrysothamnus viscidiflorus				
Age	8	8		
Canopy Volume	.26	.82		
Deepest Root	160	145		
Aster canescens				
Canopy Volume	0.22	0.36	0.18	0.26
Deepest Root	136	155	144	138
$\bar{x}$ root density by depth:				
50 cm	0.28	.023	0.38	--
100 cm	0.01	.020	.285	--
150 cm	0.00	.003	--	--
Stipa comata				
Canopy Volume	.043	--	.317	--
Deepest root	134	160	122	138
$\bar{x}$ root density by depth				
50 cm	.085	--	.030	.085
100 cm	.025	--	.040	.105
Oryzopsis hymenoides				
Canopy Volume	.263	--	.179	
Deepest root	120	125	112	
Cymopterus terebinthinus				
Canopy Volume	.219	--	--	--
Deepest Root	141	160	124	155
$\bar{x}$ root density by depth				
50 cm	--	.368	--	--
100 cm	--	.010	--	--
Atriplex spinosa				
Deepest root	195			

-- Not Sampled

Appendix A. (Continued)

Depth to deepest root (cm), age (yr), canopy volume (m^3), and mean root density (g/dm^3) for other plants on the Hanford Site.

	Plant Number
Eriogonum nivium	#1
Deepest root	150
Lactuca serriola	
Deepest Root	84
Balsamorhiza careyana	
Deepest root	150

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